Phase II Project Summary

Firm: Physical Sciences Inc.
Contract Number: NNX09CA15C
Project Title: Pulsed ElectroGasdynamic Thruster for Attitude Control and Orbit Maneuver

Identification and Significance of Innovation: In the Phase I program we successfully demonstrated the feasibility of the Pulsed ElectroGasdynamic (PEG) thruster for attitude control and orbital maneuvering. In this thruster, propellant gas is introduced into the thrust nozzle through a fast acting gas valve where a short, high voltage pulse is applied to break down and heat the propellant gas. The heated gas expands in the nozzle generating a high impulse (~mN-s per pulse) at a high specific thrust (120 μN-s/joule). The specific impulse (Isp) will be in the range of 500~1500 sec. This process can be repeated at a frequency to meet the spacecraft thrust requirements. The thrust generating mechanism of the proposed thruster is gasdynamic expansion, not magnetohydrodynamic interaction. The proposed thruster is different from the conventional pulsed electrothermal thruster in that the joule heating of the propellant takes place as the propellant gas expands through the divergent nozzle, thereby eliminating the heat and momentum losses at the nozzle throat.

Technical Objectives and Work Plan: Based on the successful Phase I work we proposed to build and test an Engineering Development Unit (EDU) system. This Phase II work involves the following tasks:

1. Build the engineering development unit (EDU) of the Pulsed ElectroGasdynamic (PEG) thruster;
2. Test the EDU thruster under simulated space environment for performance characterization;
3. Develop conceptual designs of the PEG thruster for small satellites to identify optimum design configurations and evaluate performance, weight and operational issues for the system.

The overall technical objective of the Phase II program is to evaluate the performance of the Pulsed ElectroGasdynamic thruster through a focused laboratory study. In the Phase I program we have demonstrated the feasibility of the Pulsed ElectroGasdynamic (PEG) thruster as a compact, light weight thruster with I_{sp} = 700 ~ 1200 sec. In the Phase II program we will develop the engineering development unit (EDU) for more detailed performance characterization.

Technical Accomplishments:

(1) The engineering development unit (EDU) thruster was built and successfully operated with electric power input. The cumulative testing exceeds over 1000 runs.
(2) A programmable pulsed electrical power supply was developed to operate the EDU thruster with precisely timed electrical energy addition.
(3) A sensitive pressure transducer was used to record the gas valve operational characteristics.
(4) A set of radiometers were used to directly measure the gas velocity coming out of the expansion nozzle.
(5) A sensitive pendulum impulse measurement system was developed and successfully utilized for impulse measurement.
(6) Fast electronic diagnostic systems were used to record the electrical power input to the thruster.

During the Phase II tests we observed that the EDU achieved high specific impulse, Isp. The radiometer measurements showed that the exhaust velocity ranges 10 ~ 20 km/s corresponding to 1000 ~ 2000 sec. Even for the mixed regime where a large amount of unprocessed cold propellant interacts with the fast moving hot gas, the Isp was around 500 sec. By improving the propellant utilization efficiency the PEG thruster will achieve the “spacecraft” specific impulse, which is defined as Impulse/(Mass of the propellant supplied to thruster × g), in 1200~ 1600 sec.

NASA Application(s): The Pulsed ElectroGasdynamic (PEG) thruster will be used for satellite mobility, such as rapidly changing position for rendezvous, attitude control, orbital maneuvering and controlled satellite constellation formation. These maneuvers require a relatively high thrust (mN ~ N) at a moderately high specific impulse (Isp ≈ 1000 sec) and a high electric efficiency (~60%). The PEG thruster will meet these requirements in a broad thrust range, from 1 mN with 10 W of electric power to 100 mN of thrust with 1 kW of electric power.

Non-NASA Commercial Application(s): The Pulsed ElectroGasdynamic (PEG) thruster will be very useful for military applications that require: (i) wide dynamic range in thrust; (ii) high Isp; and (iii) high electrical efficiency. For purely commercial applications, the PEG thruster will be useful for satellite station keeping, orbit raising, and attitude control. For such applications the following advantages of the PEG thruster can be fully exploited: (i) various kinds of propellant gas can be used; (ii) thrust level can be adjusted by changing pulse frequency over 2~3 orders of magnitude; (iii) the life time of the thruster hardware will be much longer than the other thrusters; and (iv) construction of the thruster is simple and can be scaled easily.

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